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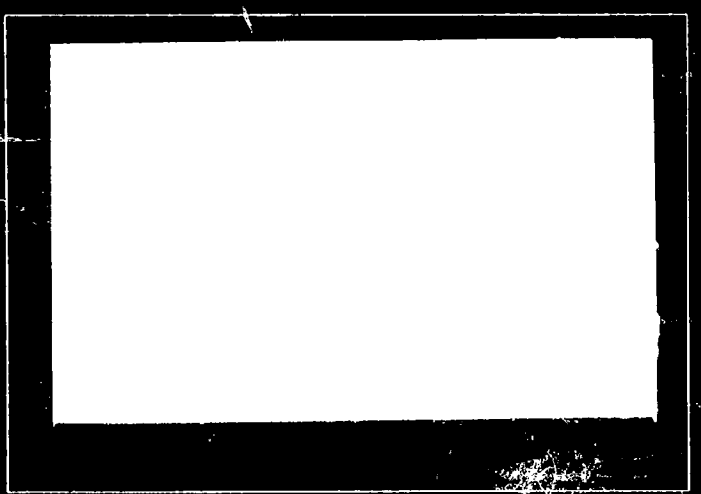

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CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

18 August, 1945

CHAMBER TESTS WITH HUMAN SUBJECTS XIII. SPECIAL TESTS OF CC-2 AND CARBON PROTECTIVE CLOTHING

by

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Report No. P-2604

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Preliminary Pages -----	a - c
Numbered Pages --------	20
Tables ----------	23
Distribution List -----	- d -

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ABSTRACT

This report describes the results obtained in some special tests on the protective characteristics of aqueous CC-2 impregnated clothing and carbon rayon clothing (#148).

It was found that previous contamination with H vapor has no significant effect on the protective value of CC-2 impregnated clothing if the [redacted] content has not been seriously lowered.

Tests on the effect of salt water showed that: (a) CC-2 suits wet with salt water during exposure to H vapor provide much greater protection than corresponding dry clothing; (b) The presence of the dry inorganic constituents of salt water has no effect on the protective capacity of CC-2 impregnated clothing.

Failure to restore the Cl+ content of impregnite-free areas on CC-2 clothing after spot testing for Cl+ content with the CWS Impregnite Testing Kit, M-1, does not seriously affect the protective capacity of the clothing. S-461 Protective Ointment was found to be more effective than S-330 Protective Ointment in restoring the effective Cl+ content.

Patch test studies showed that severe burns result from wearing H or HN contaminated carbon rayon cloth (#148) when substances such as oil, S-330 Protective Ointment, or water, are added to the cloth. Under the same conditions contaminated but untreated cloth produces negative or minimal reactions.

56AA 19744

TABLE OF CONTENTS

TEXT	Page No.
ABSTRACT	b
INTRODUCTION	1
A. Authorization	1
B. Statement of Problem	1
C. Known Facts Bearing on Problem and Theoretical Considerations	1
D. Previous Work Done at This Laboratory	5
EXPERIMENTAL	
A. Procedure for Chamber Tests	5
B. Tests of CC-2 Impregnated Clothing	6
1. The Effect of Previous Contamination with H Vapor	6
2. The Effect of Salt Water	8
3. The Effect of Variation in Wettability	11
4. The Effect of Spot Tests for Cl+ Content	13
C. Tests of Carbon Clothing	14
1. The Effect of Oil, S-330 Protective Ointment and Water on Contaminated Clothing	14
SUMMARY AND CONCLUSIONS	17
RECOMMENDATIONS	19
ACKNOWLEDGMENT	20
APPENDICES - 4	

INTRODUCTION

A. Authorization

1. This work was authorized under Project 547/41, "Maintenance, Bureau of Ships", dated 16 December 1940. The problems which were proposed for study were given in Bureau of Ships letter S-S77-2 (Dz), Serial 811 of 17 December 1940.

B. Statement of Problem

2. The purpose of this investigation was to determine by means of chamber tests, the effect of the following factors on the protection afforded by aqueous process CC-2 impregnated clothing:

(a) Previous contamination with H vapor.
(b) Salt water,
(c) Variation in wettability.
(d) Spot tests for Cl+ content.

3. In addition, a study was made, by means of patch tests, to determine the effect of oil, S-330 Protective Ointment, and water on carbon clothing (Carbon Rayon #148) contaminated with H or HN.

C. Known Facts Bearing on Problem and Theoretical Considerations

4. As the result of both chemical and physiological (chamber) tests conducted at this Laboratory and by other investigators, it has been quite definitely established that the protection afforded by CC-2 impregnated clothing is primarily a function of the magnitude of the leakage of vapor through the clothing. Thus any factors which might increase or decrease this leakage would be expected to influence the protective capacity of the clothing.

5. In 1-1/2 layer "man break" chamber

tests of Navy aqueous CC-2 impregnated clothing (CC-2 + 25% ZnO + 75% CP + 3.75% PVA + 9% dye), as carried out at this Laboratory, it has been found that the average number of successive daily exposures at CT 1200 (60 min.) and at 90°F - 65% R.H. which may be tolerated by the same subject is 4.5+. This signifies that after 4 to 5 exposures, the cumulative effects of the leakage of H vapor through the clothing have been such as to produce an intense erythema (E) or worse on some part of the body.

6. In connection with the effect of previous contamination on the protection afforded by CC-2 clothing, chemical tests (unpublished data) have shown that the total leakage of H vapor during an initial series of 4 successive daily exposures at CT 1200 (60 min.) is very close to the same as the total leakage during a subsequent second series of 4 exposures. This indicates that the products resulting from the reaction of H and the CC-2 on the clothing do not have any marked effect on the leakage characteristics under "man break" test conditions. This unchanged leakage, in addition to the fact that only negligible loss of Cl+ results from 4 or 5 exposures at CT 1200 (60 min.) leads to the belief that previous contamination with H vapor should have no significant effect on the protective characteristics of the clothing as long as the Cl+ content has not been seriously lowered.

7. An evaluation of the degree of protection provided by wet CC-2 clothing was considered desirable since one of the most likely tactical situations in which protective clothing might prove necessary is in connection with landing operations, under which conditions it can be expected that the clothing will become wet with salt water. Other chemical leakage tests (unpublished data) have shown that one of the factors which influence the extent of H vapor leakage through CC-2 clothing is the relative

humidity of the air stream used in the test. In these tests it was found that the leakage increases as the relative humidity is decreased. This indicates that the presence of moisture is beneficial and that wet clothing as well as a humid atmosphere might be expected to result in an increased protective capacity for CC-2 impregnated clothing.

8. At the same time it was considered desirable to determine the protection afforded by clothing which had been wet with salt water and then allowed to dry. This represents an evaluation of the effect of the inorganic constituents of salt water on the protective capacity of CC-2 clothing and also is of significance in use of the clothing under Service conditions. At the present time no chemical leakage data are available for clothing treated in this manner.

9. Since the pertinent data point to a significant relationship between the wetness of protective clothing and the protection provided by the clothing, it was indicated that the wettability of the clothing, i.e., the readiness with which the clothing absorbs moisture, might also be an important factor in determining the protective value. If wet CC-2 clothing is more effective than dry clothing in resisting penetration of H vapor, it was considered probable that readily "wettable" clothing would exhibit more satisfactory protective characteristics than water resistant (low wettability) suits. Accordingly, a study of the effect of variation in wettability was included in this investigation.

10. Present directives for Service use of CC-2 impregnated clothing provide for periodic testing of the clothing for Cl+ content to determine if reimpregnation is necessary. The CWS Impregnite Testing Kit, M-1, has been adopted for this purpose. (cf. Memorandum to the Director, "Evaluation of CWS Kits for Field Determination of the Protective Value of Impregnated Clothing", dated 1 April 1943). Using

this method of testing, an area of about 0.2 in^2 (0.5 in. diameter) is denuded of impregnite. It was recommended in Memorandum to the Director, "The Use of Protective Ointment to Restore the Protective Value of Test Spots Denuded by the CWS Impregnite Testing Kit, M-1", dated 1 April 1944, that S-461 (10%) Protective Ointment be used in conjunction with the CWS Field Kit to restore the denuded area after test. Chamber tests were included in the present investigation to give an evaluation of the loss of protective capacity resulting from the impregnite-free areas and also to give an evaluation of the effectiveness of Protective Ointment in restoring any observed loss.

11. Several indications of the hazards involved in the use of carbon clothing for protection against vesicant vapors were obtained during the course of chamber tests of carbon-rayon cloth #148. (cf. NRL Ltr. to BuShips C-S77-2(459-HWC/JHH), May 1, 1945). In a test in November 1944, a subject wearing a carbon-rayon suit (#148) contaminated with 100-120 γ H/$cm.^2$ (seven exposures to H vapor at 1200 CT (60 min.)each) accidently spilled fuel oil on his suit. Vesication resulted on the subjacent area. The same results were observed when, at a later date, eight men intentionally applied fuel oil to their clothing 1 - 2 hours before a fourth exposure (CT 1200 each). This clothing contained 60 - 70 γ H/$cm.^2$. Plate 1 in the Appendix shows the nature of the burns received by some of these subjects. The photographs, taken 8 days after the application of the oil, clearly indicate the effects produced by this treatment.

12. During another series of chamber tests of carbon-rayon clothing(#148) involving successive daily exposure to H vapor at CT 1200 (60 min.) and continuous wear of the clothing, severe neck burns were incurred by the subjects after about five exposures, at which time the rest of the body was relatively unaffected. The clothing contained 75 - 90 γ H/$cm.^2$. In a similar test, differing only in that no S-330 Protective Ointment was used on the

neck during exposure, the neck burns were minimal, although the clothing contained 90-110 YH/cm.^{2}. This led to the belief that the ointment was responsible for the reactions produced in the first series.

13. The deleterious effects of oil and S-330 ointment on contaminated carbon rayon clothing observed in these tests were believed to be due to a leaching or eluting action. The present series of patch tests was designed to secure preliminary quantitative data on the hazards represented by these and other similar agents, such as water and perspiration, as well as to secure information regarding the mechanism involved.

D. Previous Work Done at This Laboratory.

14. No previous tests have been conducted at this Laboratory with the purpose of evaluating the effects studied in this series of tests. This report is the thirteenth of a series on "Chamber Tests with Human Subjects", in which the results obtained in the evaluation of various protective devices against the vesicant effects of persistent chemical warfare agents are reported.

EXPERIMENTAL

A. Procedure for Chamber Tests

15. The operation of the NRL chamber is described in detail in NRL Report No. P-2208, dated 22 December 1943. The general procedure for conducting chamber tests is also described in that report.

16. The chamber tests involved in the present investigation were conducted as 1 or 1-1/2 layer "man break" tests. In these tests each man exposed in the chamber was supplied with the following protective equipment:

(a) Navy diaphragm mask, Mark III or IV (with CC-2 impregnated sleeves on the hose connecting tubes).
(b) CC-2 impregnated Arnzen suit.
(c) CC-2 impregnated rib knit shorts for 1-1/2 layer tests or Standard Navy shorts for 1 layer tests.
(d) Standard Navy undershirt (skivvy shirt - unimpregnated).
(e) CC-2 impregnated cotton socks (2 pair).
(f) CC-2 impregnated elbow-length wool gloves.
(g) Overshoes (Arctics).
(h) Protective Ointment (S-330 NCIII) for face and neck.

17. The subjects were given successive daily exposures to H vapor in the chamber under the following conditions:

(a) CT = 1200 (60 min.)
(b) Temperature = 90°F ± 0.2°F.
(c) Relative Humidity = 65% ± 3%
(d) Wind Velocity = 2 - 2.5 m.p.h.

18. The clothing was worn by the subjects for 4 hours after a chamber exposure. The men were examined and read by the Medical Officer before each exposure, and each subject was withdrawn from the test when he had incurred a reading of E (intense erythema) or greater on any part of his body. The successive daily exposures were continued until all the men had "broken" i.e., reached a reading of E or greater. The average number of exposures tolerated was used as the basis for evaluating the protection given by the clothing.

B. Tests of CC-2 Impregnated Clothing.

(1) The Effect of Previous Contamination with H Vapor.

19. The effect of previous contamination

with H vapor on the protective capacity of CC-2 impregnated clothing was determined by means of two successive "man break" tests on the same set of clothing. After one group of subjects wearing the clothing had "broken", the clothing was issued to a second group for another similar test. CC-2 aqueous impregnated suits were used (CC-2 + 25% ZnO + 75% CP + 3.75% PVA + 9% dye). The first test was conducted as a 1 layer test (no protective shorts) and the second was conducted as a 1-1/2 layer test (CC-2 impregnated rib-knit shorts) with a concurrent 1 layer control test using new clothing. The results obtained are given in Table I. The detailed individual data (cf Tables IX through XI and Table XXII in Appendix II) for these tests, as well as for all subsequent tests are given in the Appendix. These data include the readings of each subject at 24 and 48 hours after the last exposure. Table XXII represents a summary of all tests.

Table I

Effect of Previous Contamination with H Vapor

Test No.	Test Started	Clothing	Type of Test	No. of Men	No. of Breaks	Av. Exp. Tolerated
1a	1/18/44	New	1 Layer	7	7	4.1
1b	2/29/44	From 1a	1-1/2 Layer	8	6	3.1+
1c	2/29/44	New (Control Test for 1b)	1 Layer	9	6	2.7+

20. Combined average values for number of exposures tolerated for all 1 layer and 1-1/2 layer tests at this Laboratory on new CC-2 aqueous impregnated clothing have been reported in NRL Report No. P-2603, "Chamber Tests with Human Subjects.XII". These values are 3.8+ for 1 layer tests and 4.3+ for 1-1/2 layer tests. It may be seen from the data in Table I that the value for exposures tolerated in

the original test (No. 1a) is in agreement with the combined average value (4.1 vs. 3.8+). The second test on the same clothing (No. 1b) gave a value which was lower than that obtained in the first test and also lower than the corresponding combined average value for 1-1/2 layer tests (3.1+ vs. 4.3+). However, the concurrent control test also gave a low value (2.7+ as compared to the combined average value of 3.8+ for 1 layer tests). In each case the difference was the same (about 30%). This indicated that the lower protective capacities were probably due to some factor other than the previous contamination. It was concluded on the basis of the above considerations that previous contamination with H vapor has no significant effect on the protective characteristics of CC-2 impregnated clothing if the Cl+ content has not been seriously lowered. This conclusion is in agreement with that derived from predictions based on chemical leakage tests.

(2). The Effect of Salt Water.

21. The initial test on the effect of salt water on the protection afforded by CC-2 impregnated clothing consisted of an arm chamber test which was conducted as a single exposure at CT 1200 (60 min.) at 90°F and 65% R.H. with 2 mph wind velocity. The operation of the NRL Arm Chamber is described in NRL Report No. P-2219, "Chamber Tests with Human Subjects, III", dated 22 January 1944.

22. In this test two subjects wore aqueous process CC-2 impregnated sleeves which had been dipped in salt water* and wrung by hand just prior to the chamber exposure. The third subject wore a similar sleeve which was allowed to dry before exposure

*The salt water used in this and all subsequent tests on the effect of salt water was prepared according to the Standard Navy Formula given in NRL Report No. P-1381.

$NaCl$	- 24.337	grams/liter
$MgSO_4 \cdot 7H_2O$	- 3.870	grams/liter
$MgCl_2 \cdot 6H_2O$	- 6.31	" "
$CaSO_4 \cdot 2H_2O$	- 1.588	" "
KCl	- 0.676	" "
KBr	- 0.0630	" "
KI	- 0.0056	" "

in the chamber. In conducting the test, the salt water treated sleeves were worn underneath a CC-2 impregnated protective jumper. In dressing the subjects, standard impregnated woolen gloves were pulled over the sleeve, rolled back to the wrist and then taped. The sleeves of the jumper were folded back and taped so that a 3" strip of the cloth to be tested was left uncovered. The clothing was worn for 4 hours after the exposure. The results of this test are shown in Table II.

Table II

Arm Chamber Test on Effect of Salt Water

Date of Test: 3/2/44

Subject No.	Condition of Sleeve	Readings 24 hours	48 hours
1	Wet with Salt Water	0	0
2	" " " "	0	0
3	Wet with Salt Water and Dried	E-	E-

23. This preliminary test indicated that no serious loss of protection was to be expected as the result of the described salt water treatments and thus a quantitative study by means of large chamber tests was initiated.

24. The large chamber tests on the effect of salt water were conducted in the following manner. One group of subjects was provided with CC-2 impregnated clothing which was dipped in salt water and wrung by hand 30 to 45 minutes before each exposure in the "man break" series. A second group was furnished with similar clothing which had been dipped in salt water, wrung by hand, and allowed to dry. This treatment was given prior to the first exposure, and was not repeated. A third group was provided with clothing which was not treated. This group was designed to serve as a control for the treated suits.

The three groups were subjected concurrently to a 1-1/2 layer "man break" test conducted in the standard manner. The data obtained in the test are given in Table III. (See also Tables XII through XIV and Table XXII in Appendix II).

Table III

Effect of Salt Water

Test No.	Test Started	Clothing	No. of Men	No. of Breaks	Av.No. of Exp. Tolerated
2a	3/14/44	Wet with Salt Water	4	0	8++
2b	3/14/44	Wet with Salt Water and Dried	4	3	3.8+
2c	3/14/44	No Treatment (Control)	3	3	3.7

25. The results of this test, as shown in Table III, provide some very significant information. The suits which were wet during the chamber exposures exhibited a much greater protective capacity than either group of dry suits. The average number of chamber exposures tolerated is shown as 8++, but at the time the test was discontinued none of the 4 subjects wearing the wet clothing had "broken". It was indicated that the presence of the dry inorganic constituents of salt water have no effect on the protective characteristics of the clothing since the value for exposures tolerated for the suits wet with salt water and then dried is in good agreement with the value for the control group (3.8+ vs. 3.7). Both of these values are slightly lower than the combined average for 1-1/2 layer tests of this type of clothing (4.3+ cf. page 7), but the difference is not considered significant.

26. The high order of protection provided by wet CC-2 clothing in these tests is in agreement with the theoretical predictions based upon chemical leakage tests as discussed in the Introduction of this report. No conclusive explanation for this superior protection,

however, has as yet been presented. It is considered possible that the mechanism consists of a mechanical trapping of the H by the moisture, followed by a more complete reaction with the CC-2 than in the case of dry clothing.

(3) The Effect of Variation in Wettability

27. To study the effect of variation in wettability on the protection provided by CC-2 impregnated clothing, chamber tests were conducted on 4 groups of clothing.

Group I. Clothing having a low wettability.
Group II. Clothing having a medium wettability.
Group III. Clothing having a high wettability.
Group IV. Same as Group III tested at a later date.

28. The wettability characteristics of each suit were measured by means of modified Draves tests on samples from each suit. This test consists of a measure of the "wetting time". A high wetting time indicates low wettability and a low wetting time high wettability. A detailed description of the procedure used in the modified Draves test as described in BuShips Ad Interim Specifications on Twill, Cotton (for Protective Clothing), R27T27 (INT) is given in Appendix IV. The data obtained in the wettability measurements are shown in Table IV.

Table IV

Variation in Wettability of Suits

Group No.	Wettability	Draves Test Time (Sec.) Av.	Draves Test Time (Sec.) Range
I	Low	228	127 - 396
II	Medium	41	17 - 81
III	High	0	None
IV	High	0	"

29. The suits for Groups I and II were selected from the supply of CC-2 plant impregnated (low CP (25%) system) clothing available at this Laboratory. Those for Groups III and IV were prepared by dipping suits similar to those in Groups I and II in a 2% Duponol solution for 5 minutes, followed by tumbler drying.

30. The data obtained in the chamber tests of this clothing are shown in Table V (See also Tables XV through XVIII and Table XXII in Appendix II).

Table V

Effect of Variation in Wettability

Test No.	Test Started	Wettability	No. of Men	No. of Breaks	Av. No. of Exp. Tolerated
3a	5/15/45	Low	6	6	8.7
3b	5/15/45	Medium	9	8	7.3+
3c	5/15/45	High	7	6	7.1+
3d	6/14/45	High	8	5	1.8+

31. The data shown in Table V, contrary to theoretical predictions, do not indicate any significant differences in protective value as the result of variations in wettability - with the exception of Test 3d, in which clothing with a high wettability gave a very low order of protection.

32. A number of complications were encountered in conducting this series of tests which it is believed were of such a nature as to make the results inconclusive. Tests 3a, 3b, and 3c were carried out during a period of high relative humidity and the clothing, after becoming damp or wet on the first exposure, did not dry out between exposures thereafter. Thus, the variation in wettability was probably of significance

only in the first exposure. In tests 3c and 3d, especially 3d, a large number of subjects (9/15) developed small vesicles on various parts of the body after relatively few exposures. These vesicles occurred mainly on areas such as the hands, wrists, forearms, and lower legs which are covered by gloves and socks in addition to the CC-2 suit. It is not known if the occurrence of these vesicles was related to the high wettability characteristics of the clothing or if it was associated with the presence of the Duponol, which probably aids in wetting the skin, thereby making it more susceptible to H vapor (cf. NRL Report No. P-2579).

33. In view of these complications, no conclusions have been drawn from this series of tests and it is planned to re-investigate the effect of wettability at a later date.

(4) The Effect of Spot Tests for Cl+ Content.

34. The evaluation of the loss of protective capacity of CC-2 impregnated clothing resulting from impregnite-free areas after spot tests for Cl+ content, and the evaluation of the effectiveness of S-461 and S-330 Protective Ointments for restoration of these areas were conducted in the following manner: 12 aqueous CC-2 impregnated suits were tested for Cl+ content by means of the CWS Impregnite Testing Kit, M-1, on the left sleeve (forearm), right shoulder, and right leg (thigh). These suits were divided into three groups for 1-1/2 layer chamber tests.

Group I. Test areas untreated.
Group II. Test areas treated with S-461 Protective Ointment.
Group III. Test areas treated with S-330 Protective Ointment.

The results of the chamber tests are given in Table VI. (See also Tables XIX through XXII in Appendix II).

Table VI

Effect of Spot Tests for Cl+ Content

Test No.	Test Started	Treatment of Spot	No. of Men	No. of Breaks	Av. No. of Exp. Tolerated
4a	4/18/44	None	4	3	3.5+
4b	4/18/44	S-461 Ointment	4	2	3.5+
4c	4/18/44	S-330 Ointment	4	4	2.0

35. In test 4a, two men "broke" at a spot tested area only. Another man broke at a spot tested area but also at another area at the same time. In test 4b, no men "broke" at any spot tested areas. In test 4c, one man "broke" at a spot tested area only, and one at a tested area and another area simultaneously.

36. The data shown in Table VI indicate that there is no serious loss of protective capacity of CC-2 impregnated clothing if the spot tested areas are not treated. For restoration of the areas, S-461 ointment appears more satisfactory than S-330 ointment.

C. Tests of Carbon Clothing

(1) The Effect of Oil, S-330 Protective Ointment and Water on Contaminated Clothing

37. Patch tests to evaluate quantitatively the harmful effects of oil, S-330 Protective Ointment and water on contaminated carbon clothing, previously observed in connection with chamber tests of carbon-rayon clothing (#148), were carried out according to the following procedure.

38. Samples 1.2 cm. in diameter were cut from carbon-rayon cloth #148 previously contaminated with H or HN vapor. The patches were taped on the flexor

surface of the forearms of subjects, so that direct contact, covered patches were obtained. An impermeable mask with an 8-10 mm. hole was placed between the patch and the skin to prevent ring burns. The contaminated side of the cloth was away from the skin in all cases. The various additional substances with which the patches were to be treated were applied when the patches were taped to the arms.

39. In a few cases, the tests were carried out with an air space between the patch and the skin. This was accomplished by placing a washer of 3/16" thickness, covered with a metal screen, between the patch and the skin.

40. The tests were run during the winter, and the subjects spent most of the time at ordinary room conditions of approximately 75°F and 30% R.H.

41. The results of all the patch tests are summarized in Table XXIII, Appendix III. It is to be noted that the loading of agent on the cloths used for the patch tests was considerably higher than that obtained in chamber tests or to be expected in field exposures. The higher loadings were used because of the lower sensitivity of the arm as compared to other parts of the body and because of the shorter period of wear.

42. It was found, as shown in Table XXIII, that severe burns resulted from the wear of H or HN contaminated carbon rayon cloth #148 when substances such as oil, S-330 Protective Ointment or water were added to the cloth. Under the same conditions, untreated cloth produced negative or minimal reactions.

43. Of the substances tested, the addition of oil produced the most severe burns. S-330 ointment acted in the same manner as oil but to a lesser degree. It was indicated that the triacetin is the responsible ingredient of the ointment.

44. S-330 ointment applications to the side of the cloth away from the skin resulted in more severe

reactions than application to the side next to the skin.

45. The "air-space" tests indicated that the increase in vesicancy of contaminated carbon-rayon cloth #148 resulting from oil or ointment treatment is due not only to a leaching action but also to a liberation of vesicant vapor from the cloth.

SUMMARY AND CONCLUSIONS

1. A number of special tests have been conducted in the course of studies of the protective characteristics of CC-2 impregnated clothing and carbon clothing. The tests on CC-2 clothing consisted of chamber tests to determine the effect of previous contamination with H vapor, the effect of salt water, the effect of variation in wettability, and the effect of spot tests for Cl+ content. The tests on carbon clothing consisted of patch tests to determine the effect of oil, S-330 Protective Ointment, and water on clothing contaminated with H or HN.

2. It was found that previous contamination with H vapor has no significant effect on the protective characteristics of CC-2 impregnated clothing if the Cl+ content has not been seriously lowered. This was demonstrated by conducting two successive "man break" tests on the same set of clothing, i.e., after one group of subjects wearing the clothing had "broken", the clothing was issued to a second group for another similar test. Comparable protection was provided in both tests.

3. Tests on the effect of salt water showed that suits wet with salt water during exposure to H vapor give much greater protection than dry clothing (8++ vs. 3.7 exposures tolerated) in concurrent tests. In this test none of the subjects (0/4) wearing the wet clothing, had "broken" at the time the test was discontinued. It was also shown that the presence of the dry inorganic constituents of salt water has no effect on the protection given by CC-2 clothing.

4. The data obtained in the tests on the effect of wettability did not indicate any significant differences in protective value based on variation in wettability. However, complicating factors arose during these tests and the results were not considered conclusive. Further tests are planned.

5. In the evaluation of the loss of protection resulting from impregnite-free areas on CC-2 impregnated clothing after spot testing for Cl+ content with

the CWS Impregnite Testing Kit, M-1, it was found that there is no serious loss of protective capacity if the Cl+ content of the spots is not restored. For restoration purposes, S-461 Protective Ointment appeared more effective than S-330 Protective Ointment.

6. Patch test studies on the effect of oil, S-330 Protective Ointment, and water on carbon rayon clothing (#148) contaminated with H or HN showed that severe burns result from the wear of such carbon clothing after addition of these substances. Under the same conditions, contaminated but untreated cloth produces negative or minimal reactions. Of the substances tested, the addition of oil produced the most severe burns. S-330 Ointment acted in the same manner as oil but to a lesser degree.

RECOMMENDATIONS

1. It is recommended that CC-2 impregnated clothing be considered satisfactory for Service use despite previous contamination with H vapor, providing the Cl+ content is above the accepted reimpregnation level.

2. It is recommended that cognizance be taken of the increased protective value of wet CC-2 impregnated clothing and that further work be conducted to exploit this advantage.

3. It is recommended that, if available, Protective Ointment be used to restore the Cl+ content of clothing areas spot tested for Cl+ content with the CWS Impregnite Testing Kit, M-1.

4. It is recommended that oil, S-330 Protective Ointment, and water be recognized as hazards in the wear of carbon clothing contaminated with H or HN.

ACKNOWLEDGMENT

The following people have participated in conducting the experimental work involved in the tests described in this report:

Medical Group:

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Technical Group:

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G. M. Gantz - Protective Clothing
H. W. Fox - " "
M. J. Curry, CSp(X) " "
A. M. Thomson - " "
F. C. Theile, CSp(X) - Preparation of H (TG)

The authors are indebted to Lt. Comdr. L. Eugene Daily (MC) USN and Lt. J. W. Clark (MC) USNR, who actively supervised and participated in conducting the physiological tests prior to October 1944.

The subjects participating in these tests were volunteer personnel from NTC, Bainbridge, Md.

Appendix I

Table VII

Physiological Readings - Legend

Symbol	Reaction
0	None
E-	Mild Erythema
E•	Moderate Erythema
E	Intense Erythema
E+	Papular Erythema
NPV	Numerous Pin-point Vesicles
V	Vesicle
NV	Numerous Vesicles

Readings of mild and questionable erythema are not included in the data on "man break" chamber tests since they are not considered significant in tests of this nature.

Table VIII

Body Areas - Legend

Abbreviation	Area	Abbreviation	Area
aaf	anterior axillary folds	kn	knees
aar	anterior arms	le	legs
ab	abdomen	lth	lateral thorax
ale	anterior legs	lum	lumbar
ar	arms	paf	posterior axillary folds
ash	anterior shoulders	par	posterior arms
athi	anterior thighs	pen	penis
ax	axillae	ple	posterior legs
bt	buttocks	pop	popliteal spaces
C_7	7th cervical	psh	posterior shoulders
cf	cubital fossae	pthi	posterior thighs
cl	clavicles	sc	scapulae
dh	dorsum of hands	scr	scrotum
dth	dorsal thorax	uab	upper abdomen
el	elbows	ulth	upper lateral thorax
fa	forearms	umar	upper medial arms
igf	intergluteal folds	umthi	upper medial thighs
il	iliac crest	uvth	upper ventral thorax
ing	inguinal	vth	ventral thorax
		wr	wrists

Appendix II

Detailed Physiological Data for Tests of CC-2 Impregnated Clothing

Table IX

The Effect of Previous Contamination with H Vapor

Test No. 1a - Original Test - New Aqueous Clothing - 1 Layer

Date Started: 1/18/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E dth,sh,ar,ax, aaf,le,thi, ing	E+ ing,thi,bt,le) 72 E dth,sh,paf)Hours
5	E dth,sh,ar,paf, scr,bt E° thi,ing,aaf	E dth,sh,ar,bt,thi, scr,ing
6	E dth,sh,ar,aaf, thi	No Readings
4	E+ scr E aaf,sh,lth, pen,ing,dth, ar	E+ ing E dth,sh,ar,paf,aaf, scr
2	E scr	E scr,ing,ax,bt) 96 E° paf,aaf,cf,thi)Hours
4	E aaf,lth,sh,cf, dth,bt,thi,le, ar,paf,pen,scr, thi,ing	E dth,sh,paf,aaf,cf, scr,bt, E° ing,thi
5	E dth,sh,paf,ax, aaf,cf,scr E° ing,ab,thi,bt	E dth,sh,ar,ax,paf,lth, thi,ab E° bt

Av. 4.1

Table X

The Effect of Previous Contamination with H Vapor

Test No. 1b - 2nd Test - Clothing from Test No. 1a - 1-1/2 Layer

Date Started: 2/29/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E dth,sc E° scr,thi,le,pop	E sc,dth E° vth,aaf,sh,cf,ar, thi,kn,le
3	E sc,paf,aaf,C_7, ar,scr E° aaf,dth,thi,kn, le,bt,pop	E sc,dth,aaf,sh E° cf,pen,vth
2	E sc,paf E° dth,ar,pen,thi, le	E aaf,lth,sh,sc,dth,ar E° cf,pen,thi,kn,bt, pop
3	E cf,aaf,ar E° sc,paf,scr,kn, pop,le	E+ sc,dth,paf E cf,ar,sh,lth E° thi,scr,pen,pop
4	E paf E° aaf,lth,sh,sc, dth,scr,pen, pop	E scr E° dth,sh,ar,paf
3*	E° scr,cf,lth,bt, pop,dth,sc,ar, thi,kn,le	E° scr,pen,thi,bt,le, cf,lth,aaf,sh,sc, dth,ar
3*	E° scr,sc,dth,ar, bt,pop,athi	E+ dth E° cf,aaf,vth,ar,lth, sc,scr,thi,bt,le, pop
4*	E° scr,cf,aaf,sh, ar,sc,dth	No Readings E° or Greater

Av. 3.1+

* Indicates, in this and subsequent tables, subject withdrawn from test for reasons other than a "break".

Table XI

The Effect of Previous Contamination with H Vapor

Test 1c - Concurrent Control Test for Test No. 1b - 1 Layer

Date Started: 2/29/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3*	E° scr,pen,sc	E° pen,cf,aaf,sh,ar,sc
3*	E° scr,pen,aaf, sc,ar	E° aaf,sh,sc,dth,pen, ing,thi
2	E scr,sc,dth,ar E° cf	E sc,paf,scr E° aaf,cf,ar,sh,dth, thi,le
2	E sc E° thi,le,dth	E° dth,pen
3	E paf E° cf,aaf,sc, dth,pop	E aaf,sh,lth,ar,sc,dth E° cf,ing,thi,le
4	E ing,aaf,paf, sc E° cf,sh,ar,lth, dth,pon,thi, bt,le	E aaf,ax,ing,thi,sc,sh E° pen
2	E sc E° aaf,vth,ar, dth,thi,le	E pen,sc,paf,dth E° sh,vth,aaf,cf,ar,scr, ing,thi,bt,pop
3*	E° scr,pen,sc, dth,ar,aaf, thi,kn,pop	E sc E° cf,lth,ar,sh,dth,scr, pen,thi,le
2	E sc,paf,sh E° cf,ar,pop, vth,dth	E sc,paf E° cf,ar,sh,vth,dth,bt, thi,le

Av. 2.7+

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Table XII

The Effect of Salt Water

Test No. 2a - Suits Wet with Salt Water during Exposure - 1-1/2 Layer

Date Started: 3/14/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
8*	E° lar	No Readings E° or Greater
6*	E° scr	E° scr,sc
6*	E° thi	No Readings
12*	E° ar	E° lar

Av. 8++

Table XIII

The Effect of Salt Water

Test No. 2b - Suits Wet with Salt Water and Dried - 1-1/2 Layer

Date Started: 3/14/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E aaf,paf,sc E° ar,ab,scr,pen	E cl,aaf,paf,sc E° cf,sh,dth,thi,le, scr
4	E sh,sc E° aaf,dth,ar, thi,kn	E sh,aaf,sc E° ar,cf,dth
5*	E° scr,sc,dth, pop,vth,aaf, cf	E aaf E° vth,sh,cf,ar,scr, thi
3	E cl E° scr,pen,sh, sc,dth,ar,pop	E° aaf,cf,sh,ar,sc, dth,scr,pen

Av. 3.8+

Table XIV

The Effect of Salt Water

Test No. 2c - Concurrent Control-No Salt Water Treatment-1-1/2 Layer

Date Started: 3/14/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E vth,aaf,sh,sc,dth E° thi,bt,cf,ar	E vth,aaf,sh,cf,ar, sc,dth
3	E aaf E° cf,lth,sc,dth, vth	E cf,paf E° sh,sc,ar,dth, thi,kn
4	E ash,vth,lth,sc E° scr,dth,ar,thi, kn,le	E aaf,sh,ar,lth,sc E° dth,le,thi

Av. 3.7

Table XV

The Effect of Variation in Wettability

Test No. 3a - Low Wettability - 1-1/2 Layer

Date Started: 5/15/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
7	E pthi,pop E° cf,kn,paf,psh, par,el,sc,dth, igf,ple	E pthi,pop E° athi,kn,ale,psh, el,sc,dth
10	E cf,psh E° aar,athi,kn, ale,paf,sc,dth	E cf,dh,wr,athi,kn, ale,psh,pthi,pop E° paf,el,C_7,sc,dth, ple
7	E cf,kn,paf,psh, sc,dth,pop E° ash,umar,aar, aaf,lth,athi, ale,el,pthi, plo	E cf,kn,paf,psh,el,sc, dth E° ash,umar,aar,ax,lth, vth,athi,ale,pthi, pop,ple
10	E paf,psh,sc,pthi, pop E° kn,dth,ple	E paf,sc,dth,pthi,pop E° ax,athi,kn,ale,psh, ple
8	E pthi,pop E° athi,kn,ale, el,ple	E pthi,pop E° athi,kn,ale,ple
10	NV psh E° cf,kn,pthi, pop	NV psh E pthi,pop E° cf,athi,kn,ale,ple

Av. 8.7

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Table XVI

The Effect of Variation in Wettability

Test No. 3b - Medium Wettability - 1-1/2 Layer

Date Started: 5/15/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
10	NPV psh E° ash,umar,cf,ax, ulth,athi,kn,ale, paf,pop,el,sc,dth, pthi,ple	NV psh E uvth,pthi,pop,ple E° ash,umar,cf,aaf, ax,lth,athi,kn, ale,paf,el,sc
7	E cl,athi,kn,ale, pthi,pop E° ple	E cl,athi,kn,ale,pthi, pop,ple E° el
3	E ash,aar,cf,athi, kn,pthi,pop E° umar,ulth,uvth, ale,psh,par,el, C_7,sc,dth,ple	E ash,aar,uvth,athi, kn,ale,pthi,pop E° umar,cf,paf,psh, par,el,C_7,sc,dth, ple
6	E psh,sc,dth E° umar,aaf,ax,lth, athi,kn,ale,paf, el,pthi,pop,ple	E umar,ax,ulth,athi, kn,ale,paf,psh,sc, dth,pop E° aar,cf
7	E ax,pthi,pop,athi, kn E° aar,cf,lth,ale, paf,psh,el,sc,dth, ple	E umar,ax,ulth,athi, kn,ale,pthi,pop,ple E° ash,aar,cf,aaf,lth, paf,psh,el,sc,dth
6	NV psh E° athi,kn,ale,pop Q	NV psh E kn,pop E° athi,pthi,ple
7	E athi,kn,pthi,pop E° umar,aar,cf,ulth, ale,paf,psh,el,sc, dth,ple	E athi,kn,ale,pthi,pop E° umar,aar,cf,ax,ulth, paf,psh,el,sc,dth,ple
10*	E° athi,kn,ale,paf, psh,sc,dth	E° athi,kn,ale,pop
10	E athi,kn,ale,psh, pop E° cf,el,sc,dth, pthi,ple	E athi,kn,ale,psh,pop E° cf,el,pthi,ple
Av. 7.3+		

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Table XVII

The Effect of Variation in Wettability

Test No. 3c - High Wettability - 1-1/2 Layer

Date Started: 5/15/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
7	NPV cf E° aar,kn,psh,sc, ple	NPV cf E° kn
9	E ax,psh E° cf,kn,paf,pop	E umar,cf,fa,ax,kn, paf,psh,sc,pop E° athi,ale,pthi,ple
5	NV cf	NV cf
8	E cf E° kn	E cf E° ash,aar,vth,kn,psh
7	NV el E° paf,psh,par, sc	NV el,par,cf E° paf,psh,sc
10*	E° cf	E° cf
4	NV psh E° cl,ash,kn	NV psh E cf E° athi,kn,ale,el

Av. 7.1+

Table XVIII

The Effect of Variation in Wettability

Test No. 3d - High Wettability - 1-1/2 Layer

Date Started: 6/14/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
1	NV fa,dh,wr E° el	NV fa,dh,wr
2*	E° kn	E° kn
1	V dh,wr E° el,kn	V dh,wr E fa,par,el
2*	E° kn,scap	E psh E° kn,el,sc
2*	E° kn	E pop E° kn,el
2	V fa E° kn	V fa NPV cf
2	NV kn	NV kn E° el
2	NV ale E° kn	NV ale,fa E cf,ing

Av. 1.8+

Table XIX

Effect of Spot Tests for Cl+ Content

Test No. 4a - No Treatment of Spot Tested Areas - 1-1/2 Layers

Date Started: 4/18/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4*	E° ash,ar,aaf,lth, sc,dth,ax	E ash,ax,sc E° lth,vth,ar,dth,bt, thi,le,cf,fa
4	E sc** E° sh,aaf,ar,dth, pop.	E sh,ar,aaf,sc,dth E° pop
3	E sh**,sc E° dth,lth,aaf,ax	E sh,vth,aaf,sc,dth E° lth,ax
3	E sc** E° cf,ar,sh,aaf, dth,pop	E° sc,dth

Av. 3.5+

** Break at Spot Tested Area

Table XX

Effect of Spot Tests for Cl+ Content

Test No. 4b - Treatment of Spot Tested Area with S-461 Ointment - 1-1/2 Layer

Date Started: 4/18/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4*	E° aaf,sc,dth	E° aaf,ar,ash,sc,dth
4*	E° sc,dth,ax	E sc,sh E° ash,ar,lth,dth
3	E sc E° cf,fa,ar,ash	E sc,dth,ash E° cf,fa,ar
3	E cf,sc E° aaf,ar,sh,dth	E ash,aaf,cf,ar,sc,dth

Av. 3.5+

Table XXI

Effect of Spot Tests for Cl+ Content

Test No. 4c - Treatment of Spot Tested Areas with S-330 Ointment - 1-1/2 Layer

Date Started: 4/18/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
2	E ash,aaf,ar,sc E° cf,dth	E cf,fa,sc,paf,ar E° ash,dth,pop
2	E sh,sc** E° aaf,dth	E ash,sc E° cf,dth,thi,kn
2	E sc E° sh,ar,lth,dth,scr,pen	E sc E° cf,ash,ar,dth
2	E sc** E° pen,sh,ar,el,dth	E ash,sc E° cf,aaf,dth,pop,pen
Av. 2.0	** Break at Spot Tested Area	

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Table XXII

Tests of CC-2 Impregnated Clothing

1. Effect of Previous Contamination with H Vapor

Date Started	No. of Men	Type of Clothing	Type of Test	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	11	12	No. of Breaks	Av. Exp. Tolerated
1/18/44	7	Original-New Aqueous Type	1 Layer		1	1	2	2	1							7	4.1
2/29/44	8	Clothing From Test on 1/18/44	1-1/2 Layer		1	3,2*	2									6	3.1 +
2/29/44	9	Control-New Aqueous Type	1 Layer		4	1,3*	1									6	2.7 +

2. Effect of Salt Water

3/14/44	4	Wet with Salt Water during Exp.	1-1/2 Layer						2*		1*				1*	None	8 + +
3/14/44	4	Wet with Salt Water and Dried	" "			2	1	1*								3	3.8 +
3/14/44	3	Control-No Salt Water Treatment	" "			1	2									3	3.7

3. Effect of Wettability

5/15/45	6	Low Wettability (228 Sec.Draves Test)	1-1/2 Layer							2	1		3			6	8.7
5/15/45	9	Medium Wettability (41 Sec.Draves Test)	" "			1			2	3			2,1*			8	7.3 +
5/15/45	7	High Wettability (0 Sec. Draves Test)	" "				1	1		2	1	1	1*			6	7.1 +
6/14/45	8	" " " "	" "	2	3,3*											5	1.8 +

(Continued on following page)

Table XXII (Cont'd.)

Tests of CC-2 Impregnated Clothing

4. Effect of Spot Tests for Cl + Content

Date Started	No. of Men	Type of Clothing	Type of Test	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	11	12	No. of Breaks	Av. Exp. Tolerated
4/18/44	4	No Treatment of Spot Test Area	1-1/2 Layer			2	1,1*									3	3.5 +
4/18/44	4	Treatment With S-461 Ointment	" "			2	2*									2	3.5 +
4/18/44	4	Treatment With S-330 Ointment	" "		4											4	2.0

Appendix III

Tests of Carbon Clothing

Table XXIII

The Effect of Oil, S-330 Protective Ointment and Water on Contaminated Clothing
Summarized Patch Test Data

Date	No. of Men	Agent	Approx. γ Agent/cm.^{2}	Type of Test	Substance Added*	Wearing Time (Hrs.)	Average Reading
11/18/44	4	H	200	Contact	-	4	E-
11/18/44	4	H	200	"	H_2O	4	E to E +
11/18/44	4	H	200	"	Oil(1)	4	V
11/18/44	4	H	250	Contact	-	4	E-
1/ 9/45	6	H	250	"	-	8	0
1/13/45	4	H	250	"	-	8	0 to E-
11/18/45	4	H	250	"	H_2O	4	E to E +
1/ 9/45	6	H	250	"	Sweat	8	E
1/13/45	4	H	250	"	Triacetin(2)	8	E to V
1/13/45	4	H	250	"	S-330(3)	8	E
1/13/45	4	H	250	"	S-330(4)	8	V
1/ 9/45	6	H	250	"	S-330(3) sweat	8	E
1/ 9/45	6	H	250	"	S-330(4) sweat	8	V
11/18/44	4	H	250	"	Oil(1)	4	V
1/13/45	4	H	250	Air space	-	8	E-
1/13/45	4	H	250	" "	S-330(3)	8	E- to E°
1/13/45	4	H	250	" "	S-330(4)	8	E to E +

(Continued on following page)

Appendix III

Tests of Carbon Clothing

Table XXIII -(Cont'd.)

The Effect of Oil, S-330 Protective Ointment and Water on Contaminated Clothing
Summarized Patch Test Data

Date	No. of Men	Agent	Approx. Y Agent/cm.^{2}	Type of Test	Substance Added*	Wearing Time (Hrs.)	Average Reading
12/16/44	4	H	400	Contact	-	8	E^o
12/16/44	4	H	400	"	Oil(1)	2	V
12/16/44	4	H	400	Air space	Oil(1)	8	V
1/18/45	2	HN-1	1300	Contact	-	8	E-
1/18/45	2	HN-1	2000	"	-	8	E
1/19/45	6	HN-1	1650	"	S-330(4)	8	E+ to V
1/19/45	6	HN-1	1650	"	Oil(1)	8	V
2/ 2/45	6	HN-3	1200	Contact	-	8	0
2/ 2/45	6	HN-3	950	"	S-330(4)	8	E-
2/ 2/45	6	HN-3	950	"	H_2O	8	E to E+
2/ 2/45	6	HN-3	150	"	S-330(4) H_2O	8	E-
2/ 2/45	6	HN-3	60	"	Oil(1)	8	E+ to V

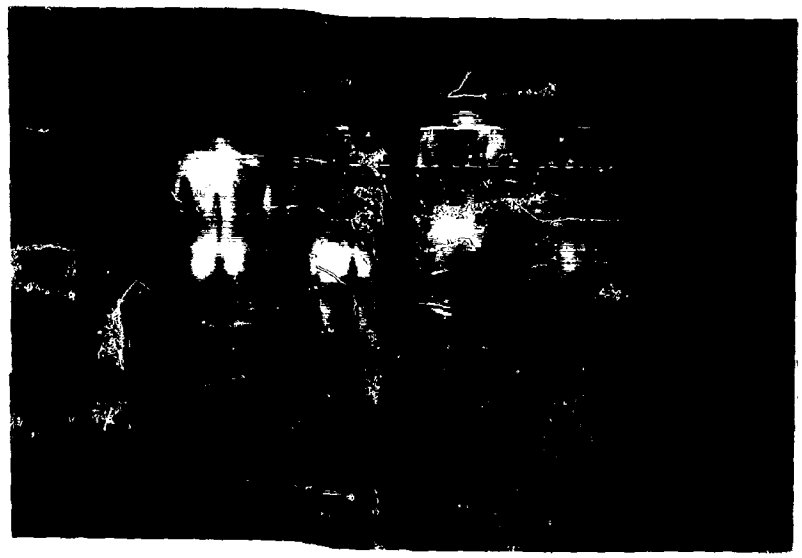
* (1) SAE No. 10
(2) Saturated aqueous solution of triacetin (approx. 7%).
(3) S-330 was applied to side of cloth next to the skin.
(4) S-330 was applied to side of cloth away from the skin.

Appendix IV

Modified Draves Test for Wettability

Ten samples of cloth, 5" x 1", are cut and conditioned at 70°F and 65% relative humidity. 500 ml. of tap water, maintained at 25± 1°C, is poured into a 500 ml. cylindrical graduate. Other test equipment consists of a 20 g. lead or brass disc, a 0.25 g. length of copper wire, and a No. 30 cotton thread. The copper wire is bent in the form of an "S" and attached to the 20 g. weight with the cotton thread so that the overall length of the weight, thread, and wire is 3 inches. A small slit is made at one end of the cloth samples for hooking on to the copper wire. Holding the end of the cloth sample, the weight is lowered into the water so that the copper wire is just touching the surface. The sample is then dropped and a stop watch started simultaneously. The watch is stopped when the cloth loses its buoyancy, as indicated by a slackening of the cotton thread, and the elapsed time is recorded.

THE EFFECT OF OIL ON H CONTAMINATED CARBON CLOTHING



Appearance of men 8 days after application of oil to carbon clothing.

Distribution

BuShips	17
Bu Med	2
OR&I	2
CNO	2
CO, Naval Unit, EA	1
CWS, Tech. Div.	4
CWS Med. Div.	1
CWS Med. Div. EA	1
NDRC	4
NRC, Wash. D. C.	2

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